Lecture 19: Electrical Distribution continued

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Remaining Course Schedule

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Date	Day	Course Topic	Chapter in Text	Assignment
11/06	Wed	Electrical Distribution cont.	13 (some from 9 and 11)	HW 6: Transformers, 3-ϕ circuits
11/11	Mon	Veterans Day (no class)		
11/13	Wed	**Exam 2**		
11/18	Mon	DC Motors, Drives, and Applications	17	Project: Electrical Distribution
11/20	Wed	DC Motors, Drives, and Applications	17	
11/25	Mon	AC Motors, Drives, and Applications	19	HW 7: DC/AC Motors
11/27	Wed	Thanksgiving Holiday - no class		
12/02	Mon	AC Motors, Drives, and Applications	19	
12/04	Wed	End of Course Review	all	Lab 11: DC / AC Motors
12/12	Thurs	**Final Exam, 6-7:50 PM**		

11/19 Tuesday - Last day to drop courses.

Grades on D2L are up to date.

Upcoming Exam

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- Exam topics will be posted on D2L by end of day
- Scheduled review session
  - Tomorrow (Thursday, 11/7) - Roberts Hall Room 102 – 6 pm
- In class. Start at exactly 9 am. Go until 9:55 am.
- 1 equation sheet allowed, front and back.

HW # 6 Assignment

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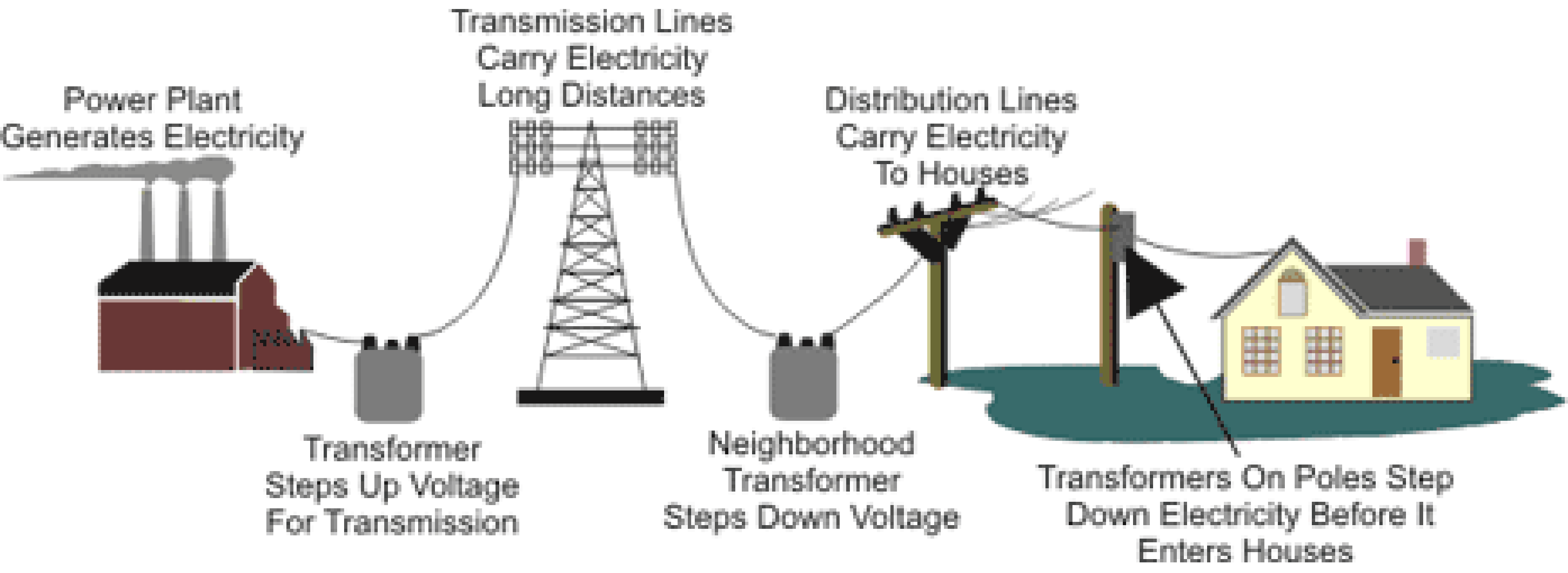
- On transformers and 3-phase circuits.
- Will be up on D2L by end of day.
- Due Monday 11/18
- However, will be very beneficial for test as both topics will be on exam 2. Worth doing as part of studying for test.

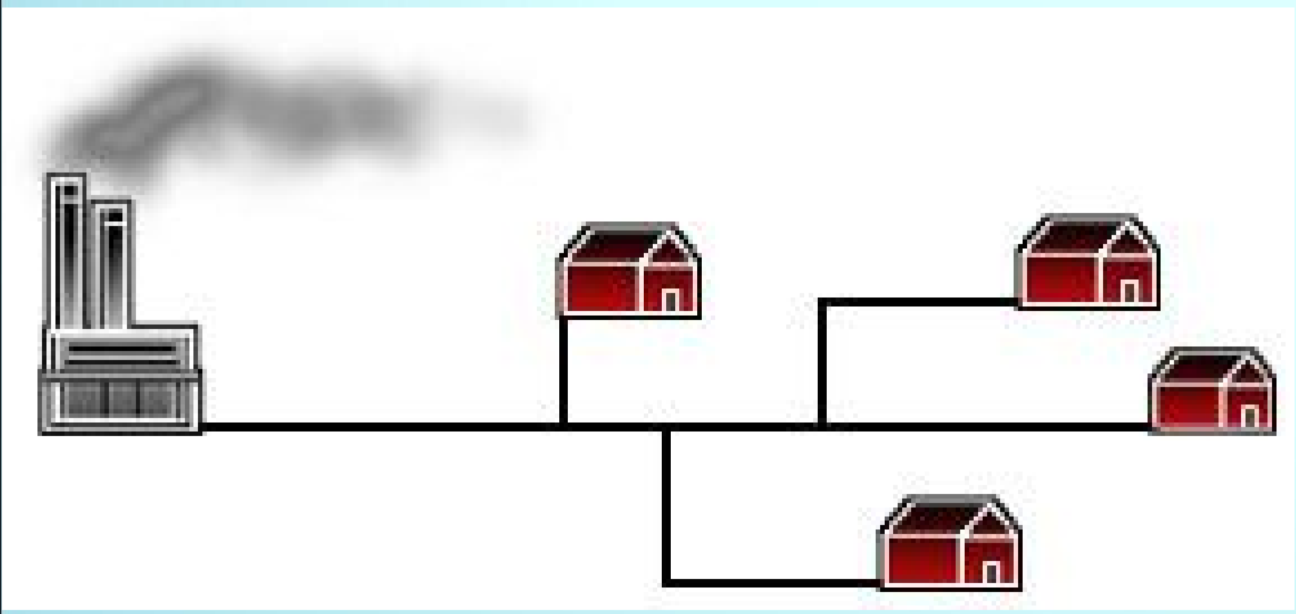
Electrical Distribution



NOTE: Book defines everything post-generation pre-use as distribution. Typically though, this system is broken-up into transmission and distribution.

Primary-side Distribution

Radial Distribution Network



- Power delivered along a single distribution path
- Cheapest to build
- Used often in rural areas
- Grid disruption → shut down entire line

Primary-side Distribution

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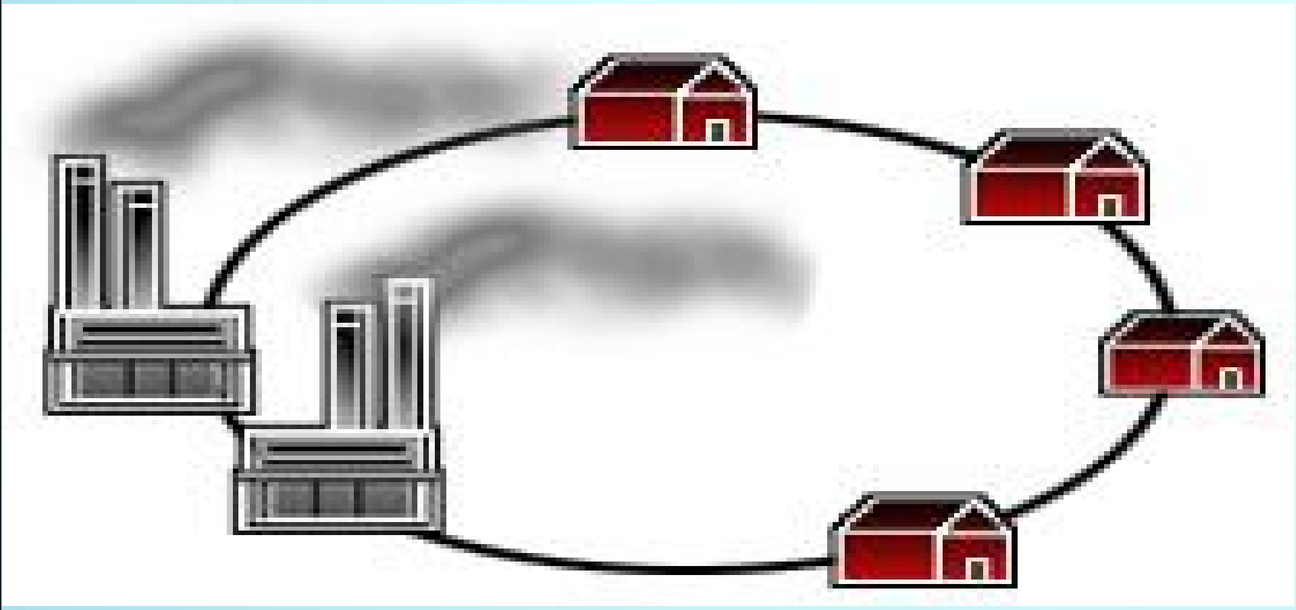
<u>Loop Distribution Network</u>



- Power delivered by loop(ed) distribution path(s)
- More expensive than radial
- Allows isolation of grid disruptions with minimal effect on customers

Secondary-side Distribution

Radial Distribution Network

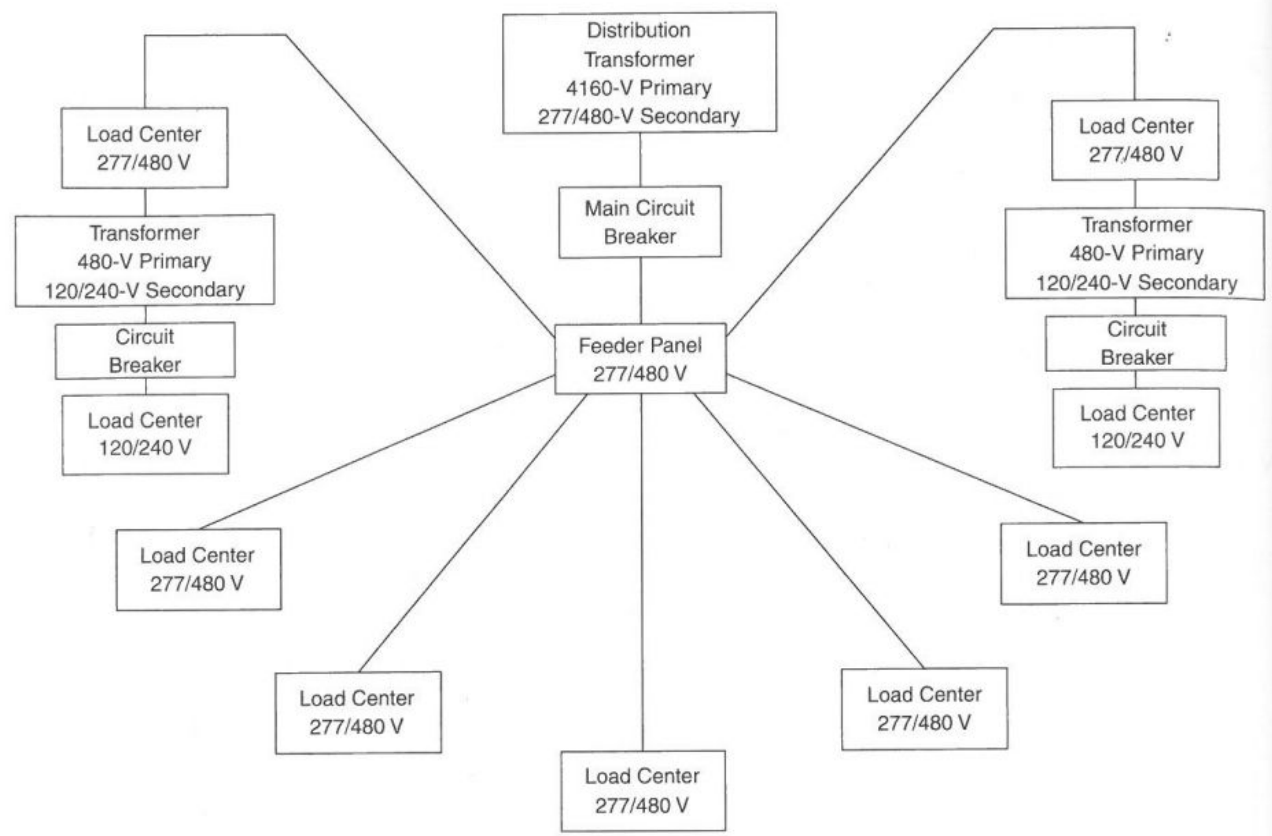


FIGURE 13–3A Consumer radial distribution system.

Secondary-side Distribution

Loop Distribution Network

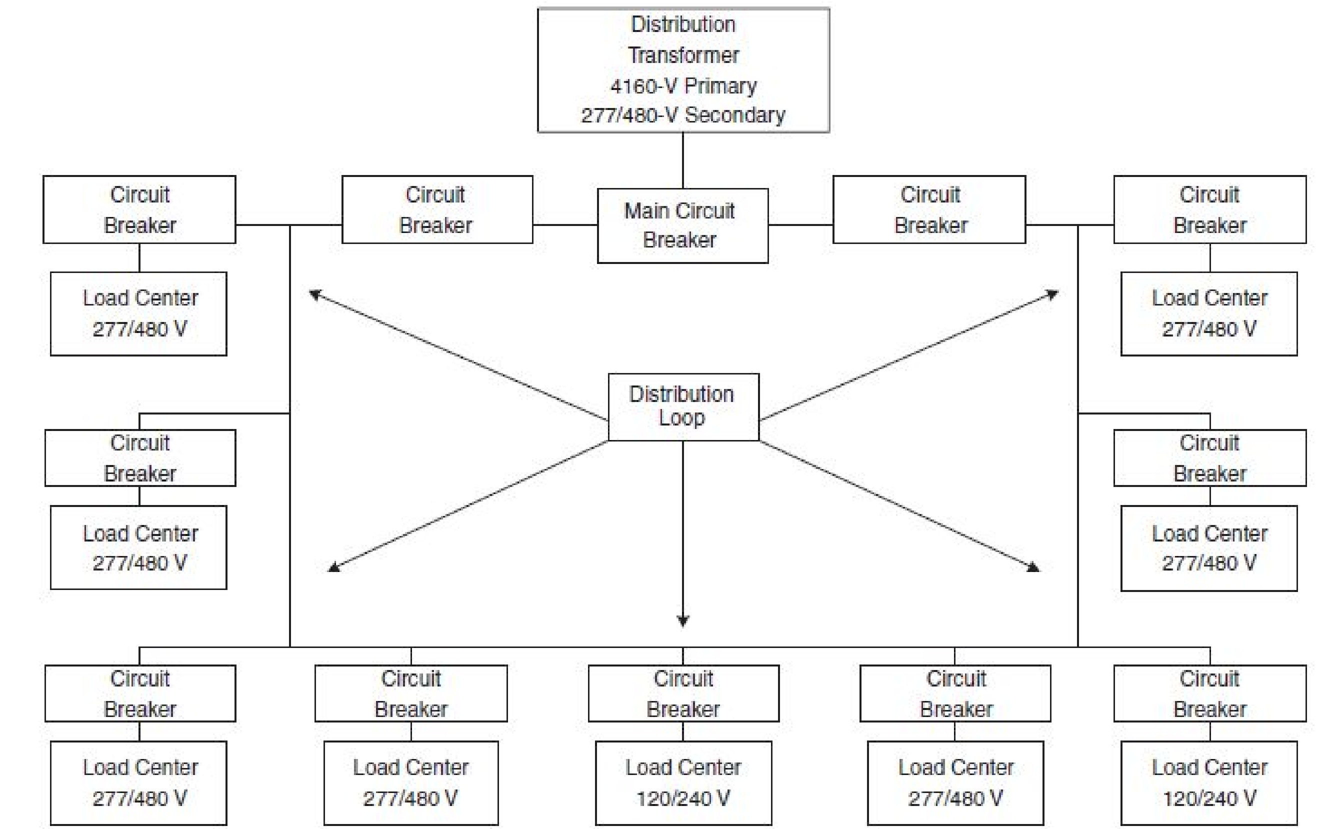
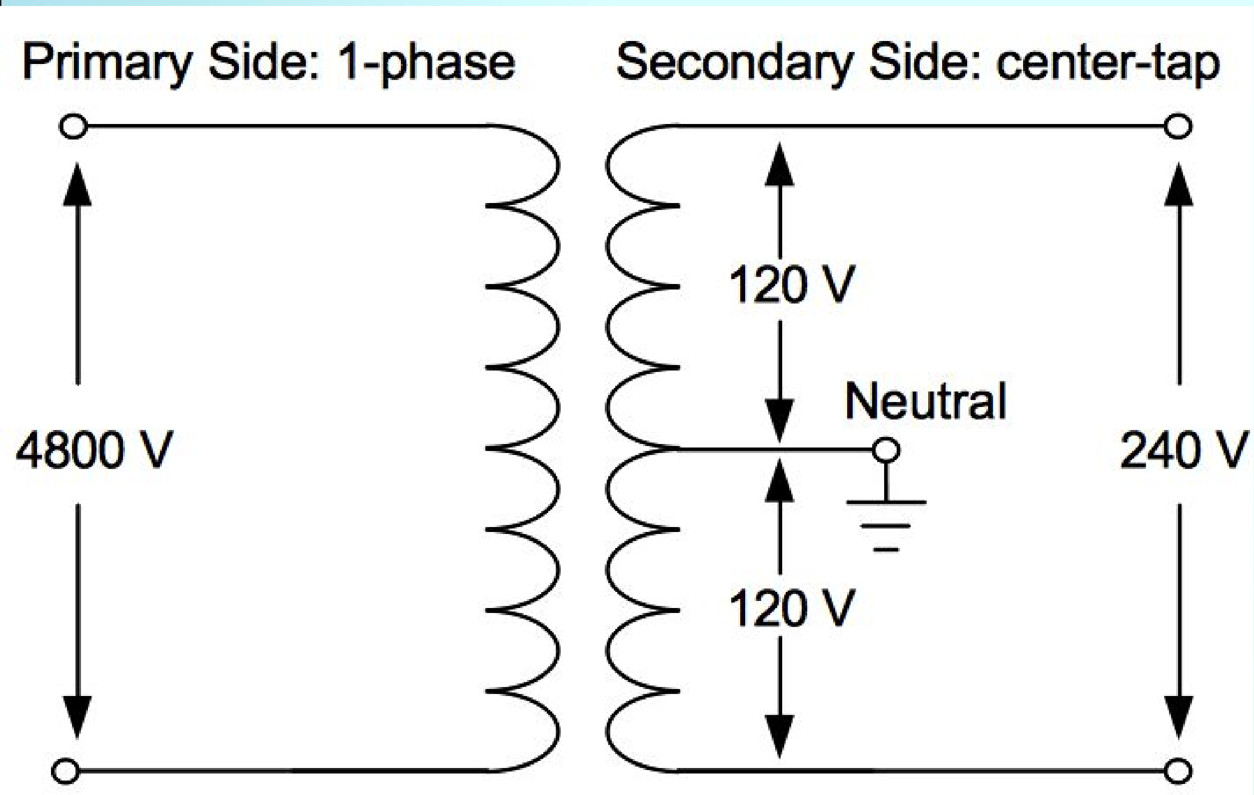


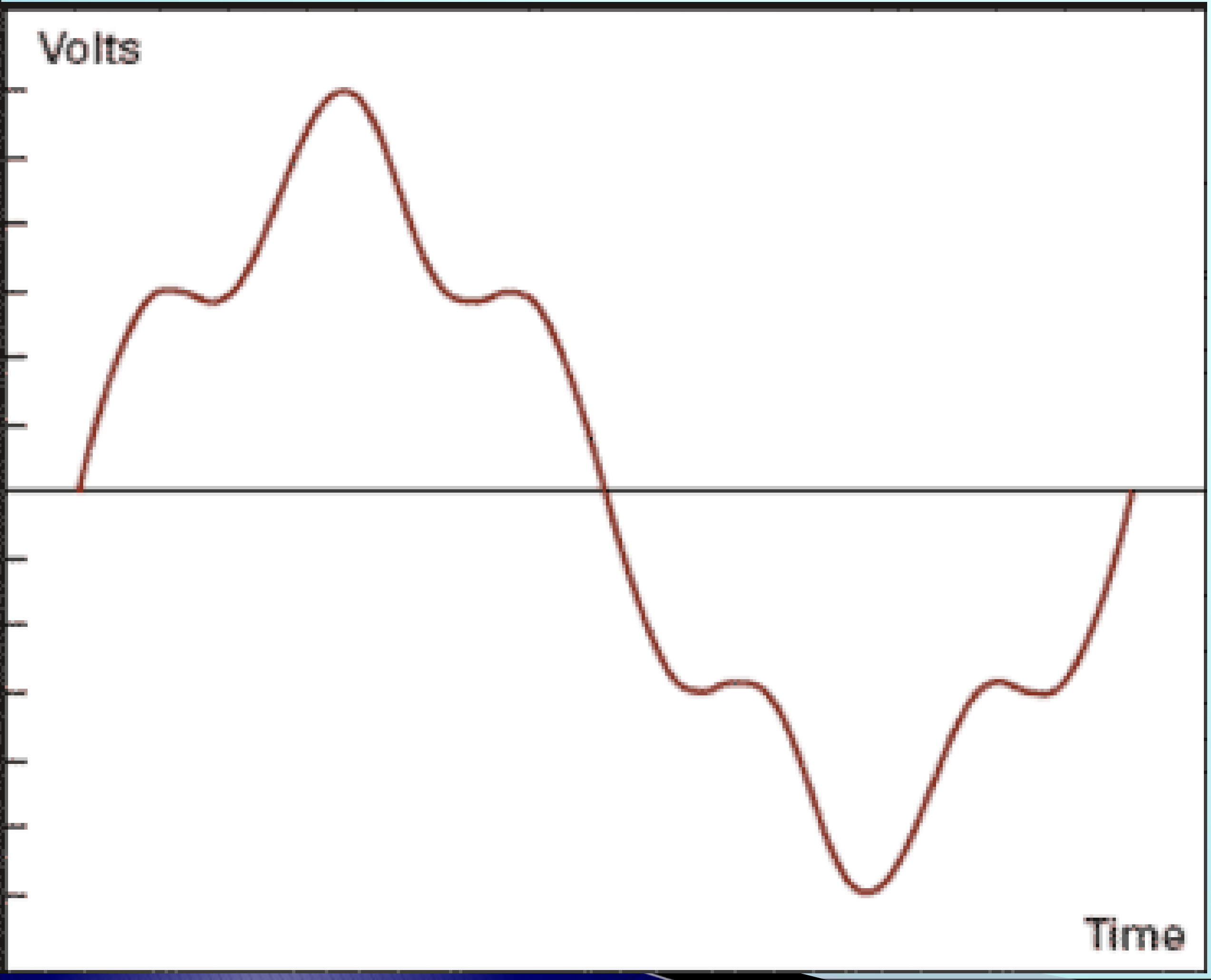
FIGURE 13–3B Consumer loop distribution system. Disconnecting means may be installed anywhere in the distribution loop to provide for isolating sections.

Residential Secondary Distribution



- Residential customers typically get 120V/240V single-phase, 3-wire service
- Taken from 1-phase of 3-phase primary distribution

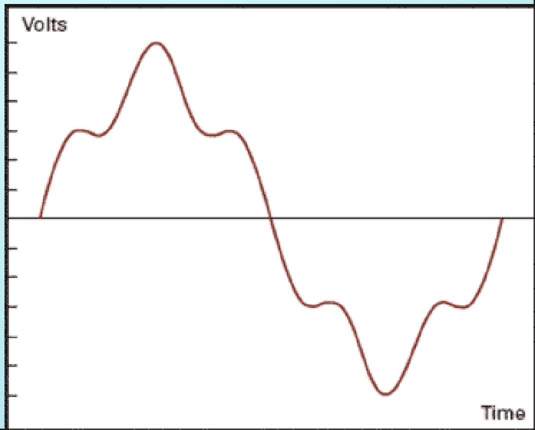
Harmonic Distortion



- Distortion in sine-wave
- Caused by non-linear loads
  - Fluorescent lights
  - Power electronics
  - Etc.
- Can cause increased power losses/conductor heating

Harmonic Distortion

- North American power systems operate at 60 Hz
- Harmonics multiples of supply frequency
  - e.g. 120 Hz, 180 Hz, etc.
- Cause additional current to flow
  - Additional power loss
  - Additional heating (3-5 percent typical) in line conductors
  - Additional heating (big! As much as 90%) in neutral
  - Might need to increase neutral conductor size if large non-linear loading on distribution circuits



Conductor Sizes

- Systems of Measurement
  - American Wire Gauge (AWG)
    - Ranges from #50 to #4/0 (#0000, pronounced #0000)
    - #50 is smallest, #4/0 is biggest

- Conductors Smaller or Larger than AWG scale measured in circular mils.

- Circular Mils:
  - Unit of area given by $A = d^2$ where d is measured in mils (1/1000 of an inch)
  - NOT equivalent to square mils

Conductor Sizes

- AWG #50 equivalent to 1 cmil (circular mil)
- AWG #4/0 equivalent to 212 kcmil (212,000 cmil)
- In U.S., generally use AWG scale, unless conductors outside that range, then use cmils.
- Note, kcmil often abbreviated MCM (means thousand circular mils)
- Both used on stranded wire or solid wire.
  - Describes cross-sectional area of metal (solid or stranded)
  - Thus, stranded wire slightly larger due to spacing between strands.

Conductor Resistivity

- All conductors have some resistance (at normal temperatures at least)

$$R = \frac{K\ell}{A} \qquad \text{(Eq. 9.6)}$$

where R = resistance of the conductor, in ohms (Ω)
K = resistivity
ℓ = length, in feet (ft)
A = area, in circular mils (cm)

- Note: Resistivity
  – More often denoted by ρ
  – More often given in Ω-m

Materials	Resistivity (K) at 20°C or 68°F	Temperature Coefficient (α) per °C*
Aluminum	17.7	0.0043
Carbon	20,000	−0.0005
Constantan	296	0
Copper	10.4	0.0043
German Silver Wire	200	0.0004
Iron wire	60	0.006
Iron (cast)	500	0.0008
Manganin	266	0.00002
Nichrome	660	0.0002
Nickel	60	0.006
Silver	9.5	0.004
Steel (soft)	90	0.0044
Steel (hard)	275	0.0016
Tungsten (annealed)	26	0.005
Tungsten (hard drawn)	33	0.005

*Average of values between 0° and 100°C

Thermal Effects

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- As temperature increases resistivity increases
- Equation in book (Chapter 9):

$$R_o = R(1 + a\,t_o)$$

R_o Is operating resistance

R Is resistance at 0° C

a Is temperature coefficient

t_o Is operating temperature

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Choosing Conductors

TABLE B–1 Allowable ampacities of insulated conductors rated 0 through 2000 volts, 60°C through 90°C (140°F through 194°F), not more than three current-carrying conductors in raceway, cable, or earth (directly buried), based on ambient temperature of 30°C (86°F).

Size AWG or kcmil	Temperature Rating of Conductor (See Table 310.13.)						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	Copper			Aluminum or Copper-Clad Aluminum			
18	—	—	14	—	—	—	—
16	—	—	18	—	—	—	—
14*	20	20	25	—	—	—	—
12*	25	25	30	20	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	30	40	45	8
6	55	65	75	40	50	60	6
4	70	85	95	55	65	75	4
3	85	100	110	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	150	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	190	230	255	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	355	420	475	285	340	385	600
700	385	460	520	310	375	420	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	450	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	520	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	560	665	750	470	560	630	2000

Correction Factors

Ambient Temp. (°C)	For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities shown above by the appropriate actor shown below						Ambient Temp. (°F)
21–25	1.08	1.05	1.04	1.08	1.05	1.04	70–77
26–30	1.00	1.00	1.00	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	—	0.58	0.71	132–140
61–70	—	0.33	0.58	—	0.33	0.58	141–158
71–80	—	—	0.41	—	—	0.41	159–176

*See 240.4(D).

Table values based on empirical thermal effects measurements on conductors.

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Voltage Drop in Conductors

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- *NEC* allows a maximum voltage drop of 3% for branch circuits
- 5% for combined feeder and branch-circuit
- Assume FULL load.

$$\%\,Voltage\ Drop = \frac{E_1 - E_2}{E_1}$$

E_1 Is source voltage

E_2 Is load voltage

Power Loss

- *NEC* allows a maximum voltage drop of 3% for branch circuits
- 5% for combined feeder and branch-circuit
- Assume FULL load.

$$P_{loss} = (E_1 - E_2) I$$

$$P_{loss} = \frac{(E_1 - E_2)^2}{R_{wire}}$$

$$P_{loss} = I^2 R_{wire}$$

Questions